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Water Quality of River Tapi, Surat Using WAWQI

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A B S T R A C T

This present study analyzes its physicochemical characteristics along with the overall water quality of Tapi River at Surat, Gujarat by undertaking one month of primary water sampling and laboratory analysis. Temperature, turbidity, pH, electrical conductivity (EC), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), nitrate N, nitrite N, ammonia, total hardness, fluoride, chloride, total alkalinity, phosphate, sodium and potassium were analysed for seventeen key water quality parameters. To obtain an understanding of water quality variation across the sampling period, descriptive statistical analysis was performed to determine minimum, maximum, mean, median and standard deviation for each parameter. All parameters were found within the permissible limit fixed by national standards (BIS and CPCB) indicating that river water is non toxic for domestic and irrigation use.

Keywords: WAWQI, Tapi, Water quality, Correlation matrix, statistics.

1. Introduction

1.1 General

Life requires water as its foundation since this solvent substance enables the survival of ecosystems and makes agricultural production possible while supporting industry and meeting domestic needs. The world lacks equal distribution of water resources, both in geographic locations and throughout yearly seasons, which creates unequal access to water (Sophocleous, 2004). Earth contains 97.5% saline water, which exists in its oceans and seas as the largest water reservoir (Oksana & Dmytro, 2021). When it comes to society, the availability of water directly influences public health, together with sanitation services, and it facilitates economic activities. Water represents an essential economic factor because its role extends to serving as a fundamental material in industrial activities and power production, together with agricultural activities. The World Health Organisation identifies 2 billion people worldwide who consume drinking water from sources containing faecal contamination, thus creating a major spread of diseases (Bain et al., 2014). Water pollution originates from the dumping of wastewater, which remains untreated or displays insufficient treatment from domestic, industrial and agricultural sectors (Manasa & Mehta, 2020).

India possesses a diverse waterway system of rivers that sustain its social-economic activities and ecological patterns (Lakra et al., 2011). It needs to dedicate renewed attention to integrated water resource management because it must handle both water quantity and water quality throughout its entire river basins. The Tapi River stands as one of the major Peninsular rivers and serves as the most essential water source for the state of Gujarat in western India. The Tapi River functions as an important research subject because it is rain-fed and receives significant human disturbances yet remains crucial for water quality assessments.

1.2 The Tapi River: Geographical and Hydrological Overview

The Tapi River starts in the Satpura ranges of Multai in Madhya Pradesh before it runs its 724-kilometre journey to reach Surat on the Arabian Sea in Gujarat. Throughout its path, the Tapi River crosses through three states of India, which include Madhya Pradesh, Maharashtra, and Gujarat, until it reaches the drainage area of 65,145 square kilometres. Topographical features in the Tapi River basin combine undulating plains with plateaus and hilly terrains in various locations.

The Tapi River basin experiences tropical conditions since southwest monsoon rains generate more than 80% of the yearly precipitation. The seasonal nature of flow in the river reaches its highest point during monsoon then decreases toward minimal levels during dry seasons. People depend on this water basin for agricultural, industrial, domestic water supply and fisheries purposes.

1.3 Urbanization and Industrialization in Surat

The city of Surat establishes itself as a fast-expanding Indian metropolis in its position on the Tapi River in Gujarat's southern territory. This Gujarati municipal centre claims the position as the state's second biggest settlement while establishing itself as a major commercial centre for western India. The population exceeds 6 million people.

Surat's rapid urban expansion produces adverse environmental effects, which harm the quality of the Tapi River water. The expansion of urban areas caused the disruption of wetlands and natural drainage systems, which decreases the river's ability to clean itself. During industrial peaks and when monsoon produces overflows, the river receives direct discharges of large amounts of raw sewage, industrial effluents, and solid waste residues. Several chemical as well as textile-based industries throughout Hazira, Udhna, Pandesara, and Sachin release multiple pollutants into the surrounding bodies of water. The water contains hazardous substances, together with heavy metals, organic and inorganic chemicals, synthetic dyes, and suspended solids. The pollution issue becomes worse due to weak enforcement efforts combined with old infrastructure systems and insufficient monitoring activities.

Fig. 1 – Sources of water pollution

2. Literature Review

(Sharma et al., 2022) The document investigates Indian River water degradation resulting from rising wastewater inflow into these essential water resources. Their research shows that various government initiatives have failed to establish acceptable water quality standards in Indian rivers. The results show why there is an urgent need for efficient water quality management and restoration programs. The research evaluates water quality parameters from 2012 to 2016 over five years in nine locations across three major Indian rivers – Beas, Sutlej, and Ganga. The analysis includes four major water quality indicators: temperature, dissolved oxygen, pH, and biochemical oxygen demand.

(Goldar & Banerjee, 2004) They look at how informal rules affect the water quality of Indian rivers, pointing out that statutory environmental regulations are insufficient to prevent or lessen pollution. This study intends to determine if spatial variations in the intensity of informal regulation correlate with spatial variations in ambient water quality. Informal regulation has increasingly been recognized as playing a role in controlling pollution, and a rapidly growing body of literature on this motivates the research. Sources of river water pollution in India are essentially the discharge of domestic sewage and industrial effluents, which introduce organic pollutants, chemicals and heavy metals.

(Alam et al., 2007) The study determines water quality in river systems by evaluating physical characteristics, chemical content, and biological measures at various testing points. The document explains how Conductance, Hardness, DO, BOD, COD, Temperature, Alkalinity, Total Dissolved Proteins, Faecal Bacteria, and Ammonia help evaluate river water quality. The study gathers Surma River water samples during rain and drought to measure physical aspects and check chemical components and microorganisms. The study showed that the river got dirtier during the rainy season, yet BOD and bacteria counts remained elevated during drought.

(Singh et al., 2005) Researchers from India studied the Gomti River water quality through statistical methods to determine pollution sources. The study worked with 9792 observations spanning 34 water quality parameters analysed through three years at eight sites. The researchers used multiple statistical procedures, including cluster analysis and four other methods, to analyse the data. Research separated the sampling locations into three major groups. This research divides all catchment areas into three types: top, middle, and bottom sections based on how they act in common. PCA and FA detected multiple hidden patterns in each stream region to explain the underlying data connection that accounted for significant variance. Pollution entered river systems because of elements taken from soil and industrial waste sites, household and industrial wastewater discharges, farm nutrients, and changes in water chemistry. The Gomti River receives harmful materials from targeted and distributed locations mainly through agricultural drainage and sewage outlets. Scientists have found that this river stands out as one of the most polluted waterways in India today.

3. Methodology

3.1 Several water quality variables were examined to understand the condition of the Tapi River pollution. These included temperature, pH, dissolved oxygen, turbidity, conductivity, biochemical oxygen demand, chemical oxygen demand, nitrate-nitrogen, nitrite-nitrogen, ammonia, total hardness, fluoride, chloride, alkalinity, phosphate, sodium and potassium.

3.2 The Weighted Arithmetic Water Quality Index method sorts water quality by purity using various water quality measurements. The WAWQI is obtained using this equation:

$$WAWQI = \frac{\sum_{i=1}^{n} Q_i W_i}{\sum W_i}$$

Where: For each parameter, Qi is the scale used to rate its quality. Each water quality parameter has a specific unit weight, called Wi. For every parameter, the quality rating scale is found by turning the value into a rating Qi computed as:

$$Q_i = 100[\frac{V_i - V_o}{S_i - V_o}]$$

Where: Vi stands for the predicted concentration of parameter i found in the analyzed water. This parameter has an ideal value of 0 in pure water; the value in other substances is studied further. The recommended standard value Si is given for the ith parameter. The unit weight for every water quality parameter is calculated using this approach

$$W_i = K/S_i$$

Where: To find K, the following formulae can be used:

$$K = \frac{1}{\sum(\frac{1}{S_i})}$$

3.3 A correlation matrix was built using Pearson’s correlation coefficient to see the relations among various physicochemical features of the Tapi River water. This method makes it possible to see if two variables are linearly related and in what way. The monthly average measurements of each parameter were the data used in the correlation analysis.

4. Results

4.1 Statics of water Parameters

Assessment of the water quality along the Tapi River during the study period revealed mostly stable and moderately changing values for most parameters. The temperature fluctuated little within a close range (from 26.028°C to 29.927°C with an average of 27.954±1.190°C), showing that the area was overall at a stable temperature. Test results indicate that turbidity was low (average 18.116 NTU±0.653), as was pH (average 8.329±0.276) and EC (0.755±0.115 mS/cm), indicating the river water had good clarity, was slightly alkaline and had moderate amounts of ions.

Even though dissolved oxygen was slightly less than what’s considered good (mean 4.894±0.311 mg/L), the BOD (5.203±0.425 mg/L) and COD (81.548±6.516 mg/L) show an average level of organic pollution that may be due to both domestic and industrial wastewaters. The Nitrate-N (0.094±0.010 mg/L), Nitrite-N (0.072±0.004 mg/L) and Ammonia (0.726±0.041 mg/L) values throughout remained in acceptable ranges and suggested that agricultural runoff and untreated sewage were unlikely during the study.

According to the Total Hardness and Total Alkalinity values (110.968±7.369 mg/L and 112.806±6.750 mg/L), respectively, the water is suitable for both drinking and crop irrigation. The concentrations recorded for fluoride were extremely low and stayed within accepted safety margins (0.010±0.007 mg/L). Chloride and Sodium were both very similar to each other and both well under their critical limits. We found that Phosphate and Potassium values were somewhat higher than average at 0.567±0.012 mg/L and 48.161±4.539 mg/L, suggesting nutrient inputs from detergents or fertilisers.

In general, median readings for all parameters were nearly as high or low as their mean values, and the low standard deviations indicated no big changes in water quality. The river meets most water quality standards for usage, but especially close attention should be paid to BOD, COD and phosphate to preserve its ecology.

Table 1 – Statistics of water parameters

Statistics	Temperature (Celsius)	Turbidity (NTU)	pH	EC (ms)	DO (mg/l)	BOD (mg/l)	COD (mg/l)	Nitrate-N (mg/l)
Minimum	26.028	17.100	8.010	0.600	4.300	4.500	70.000	0.080
Maximu	29.927	19.000	8.780	0.900	5.300	5.800	90.000	0.110
Mean	27.954	18.116	8.329	0.755	4.894	5.203	81.548	0.094
Median	27.717	18.300	8.240	0.700	4.900	5.200	83.000	0.095
Std Dev	1.190	0.653	0.276	0.115	0.311	0.425	6.516	0.010

Nitrite-N (mg/l)	**Ammonia (mg/l)**	**Total Hardness (mg/l)**	**Fluoride (mg/l)**	**Chloride (mg/l)**	**Total Alkanity(mg/l)**	**Phosphate (mg/l)**	**Sodium (mg/l)**	**Potassium (mg/l)**
0.065	0.650	100.000	0.000	29.048	98.000	0.055	16.550	40.000
0.080	0.800	123.000	0.020	30.947	123.000	0.059	17.780	55.000
0.072	0.726	110.968	0.010	30.027	112.806	0.057	17.311	48.161
0.072	0.730	110.000	0.010	29.972	113.000	0.057	17.440	49.000
0.004	0.041	7.369	0.007	0.637	6.750	0.001	0.371	4.539

WAWQI

The Weighted Arithmetic Water Quality Index for the Tapi River for the study period was determined to be 37.049. As classified by WAWQI, the river water comes under the “good” category, meaning that it is already good enough for drinking and domestic work after small treatment. The key parameters measured, pH, turbidity, dissolved oxygen and nutrient levels, were found to be moderate and remained acceptable, as shown by this classification. Although there were slight elevations in BOD and COD, this did not seriously affect the water’s overall quality. The WAWQI grouping of complex data into a single index helps make understanding and conveying water quality status much simpler. Ongoing observation and spot actions are highly recommended to support or enhance the quality of the local waters.

Table 2– Weighted Arithmetic Water Quality Index

Parameters	**$1/S_n$**	**$W_i=k/S_n$**	**V_o**	**V_n/S_n**	**$Q_n=V_n*100/S_n$**	**W_nQ_n**
Temperature (Celsius)	0.029	0.001	0.000	0.799	79.869	0.10
Turbidity (NTU)	0.100	0.004	0.000	1.812	181.161	0.80
pH	0.118	0.005	7.000	0.886	88.600	0.46
EC (ms)	1.000	0.044	0.000	0.755	75.484	3.32
DO (mg/l)	0.143	0.006	14.600	1.277	127.700	0.80
BOD (mg/l)	0.167	0.007	0.000	0.867	86.720	0.64
COD (mg/l)	0.100	0.004	0.000	8.155	815.484	3.59
Nitrate-N (mg/l)	0.022	0.001	0.000	0.002	0.209	0.00
Nitrite-N (mg/l)	0.333	0.015	0.000	0.024	2.394	0.04
Ammonia (mg/l)	0.833	0.037	0.000	0.605	60.538	2.22
Total Hardness (mg/l)	0.002	0.000	0.000	0.185	18.495	0.00
Fluoride (mg/l)	0.667	0.029	0.000	0.007	0.667	0.02
Chloride (mg/l)	0.001	0.000	0.000	0.030	3.003	0.00
Total Alkanity(mg/l)	0.002	0.000	0.000	0.188	18.801	0.00
Phosphate (mg/l)	10.000	0.440	0.000	0.567	56.700	24.97
Sodium (mg/l)	0.005	0.000	0.000	0.087	8.655	0.00
Potassium (mg/l)	0.020	0.001	0.000	0.963	96.323	0.08

Correlation

The matrix prepared for the Tapi River’s physicochemical measurements reveals connections between these factors and possible pollution sources. Relationships are strong if the correlation coefficient is close to +1 or -1, but weak or nonexistent when the value is close to zero.

Total hardness and dissolved oxygen were found to have a modest positive correlation (r = 0.391), showing that mineral salts in water may help keep oxygen dissolved because they hold back microbes or balance the water’s acidity. Likewise, both turbidity and potassium tended to increase as DO increased, which may indicate that gas exchange was affected by the movement of water and potassium ions.

In addition, DO demonstrated a moderate connection that nitrate and COD levels tend to increase at the same time. Such an inverse relationship should occur since both chemical oxygen demand and nitrogenous waste use up the naturally available oxygen in the water.

It was found that Biochemical Oxygen Demand (BOD) had a moderate positive connection to nitrate (r = 0.495), suggesting that this pollution occurs together with many nutrients from agricultural runoff. At the same time, BOD was negatively related to most other characteristics, such as DO (an association of –0.237), turbidity (–0.246) and total hardness (–0.325), indicating that the rise in organic matter caused oxygen shortages and a higher amount of minerals.

The correlation between Electrical Conductivity (EC) and various parameters was lower, but a small positive link with chloride (r = 0.243) indicates EC changes might be partly related to chloride ions. It was clear that there was a small negative relationship between EC and DO (r = –0.232) and ammonia (r = –0.257), possibly because these ions competed with oxygen for space.

Phosphate correlated moderately with total alkalinity and weakly with chloride, suggesting it relates to adverse effects of nutrients and wastewater. Phosphate negative relations with both DO (r = –0.234) and EC (r = –0.226) suggest it plays a part in promoting the removal of oxygen from the water.

Chloride and fluoride had only limited associations with the other checked parameters, but chloride showed a positive relationship with both BOD (r = 0.321) and ammonia (r = 0.249) which hints at sewage or industrial discharge sources. While potassium was linked to higher amounts of DO and ammonia, it also showed a strong negative relation with COD. This result indicates that, at the same time, nutrients could be increasing and organic impurities decreasing in wastewater.

Table 3– Correlation Matrix

	Turbidity (NTU)	*pH*	*EC (ms)*	*DO (mg/l)*	*BOD (mg/l)*	*COD (mg/l)*	*Nitrate-N (mg/l)*	*Nitrite-N (mg/l)*	*Ammonia (mg/l)*	*Total Hardness (mg/l)*	*Fluoride (mg/l)*	*Chloride (mg/l)*	*Total Alkanity (mg/l)*	*Phosphate (mg/l)*	*Sodium (mg/l)*	*Potassium (mg/l)*
Turbidity (NTU)	1.000															
pH	-0.025	1.000														
EC (ms)	0.103	-0.051	1.000													
DO (mg/l)	0.258	0.171	-0.232	1.000												
BOD (mg/l)	-0.246	-0.209	-0.133	-0.237	1.000											
COD (mg/l)	-0.216	-0.325	0.136	-0.436	0.040	1.000										
Nitrate-N (mg/l)	0.180	-0.111	0.001	0.181	0.495	-0.077	1.000									
Nitrite-N (mg/l)	-0.193	-0.101	-0.239	-0.349	0.182	0.314	-0.057	1.000								
Ammonia (mg/l)	-0.096	-0.243	-0.257	0.075	0.155	-0.194	0.024	-0.061	1.000							

Total Hardness (mg/l)	0.382	-0.083	-0.226	0.391	-0.325	-0.279	0.087	-0.169	-0.015	1.000						
Fluoride (mg/l)	-0.060	0.055	0.000	-0.251	-0.115	0.037	-0.259	0.036	0.036	-0.119	1.000					
Chloride (mg/l)	-0.089	-0.059	0.243	-0.049	0.321	0.070	0.178	-0.015	0.249	-0.389	0.070	1.000				
Total Alkanity(mg/l)	0.036	0.070	-0.183	-0.044	0.081	-0.121	-0.002	-0.134	0.066	-0.070	0.282	0.120	1.000			
Phosphate (mg/l)	0.223	-0.011	-0.226	-0.234	0.065	-0.249	0.047	0.059	-0.152	-0.105	0.094	0.195	0.456	1.000		
Sodium (mg/l)	0.046	-0.037	-0.158	0.130	0.074	-0.329	-0.166	-0.084	0.095	0.151	0.076	0.031	0.249	0.122	1.000	
Potassium (mg/l)	0.130	-0.073	-0.043	0.270	-0.090	-0.485	0.182	-0.183	0.298	0.230	0.161	0.076	-0.132	0.055	0.072	1.000

5. Conclusions

- As a result of this study, we understand the water quality in the Tapi River and its overall condition over one month. Seventeen key water quality parameters were analysed, which led to a number of important findings.
- The parameters tested, such as temperature, pH, turbidity, EC and several important hardness and alkalinity levels, complied with the requirements for both drinking and irrigation. The river showed a basic pH value (mean pH = 8.329), along with fair turbidity (mean = 18.116 NTU), which may be caused by surface runoff.
- The average dissolved oxygen (DO) was 4.894 mg/L, which is somewhat lower than the usual benchmark, suggesting likely organic pollution or insufficient air delivery. These findings are also confirmed by BOD (5.203 mg/L) and COD (81.548 mg/L) values, which indicate some organic matter and chemical pollutants coming from domestic or industrial sources.
- Figures from the analysis demonstrated that the concentration of nitrate, nitrite and ammonia were alright, but phosphate slightly increased, probably due to detergents or fertilisers. Again, the level of potassium was high, which indicates that humans or agriculture have affected the soil.
- According to the WAWQI, the water quality of the river was classified as “good,” with a value of 37.049. Therefore, the water can be used in homes with not much treatment, and there isn’t much environmental stress on it currently.
- With the correlation matrix analysis, we were able to find out how each parameter is attached to others. A strong negative relationship was found between DO and COD (r = –0.436) as well as DO and nitrite (r = -0.349), proving that biological wastes were using up oxygen. The fact that BOD and nitrate show a strong link (r = 0.495) suggests that both are caused by sewage or fertilizer runoff. Analysing the relationships between phosphate, alkalinity, and hardness allows for predicting both the pollution load and the likely sources of pollutants.

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